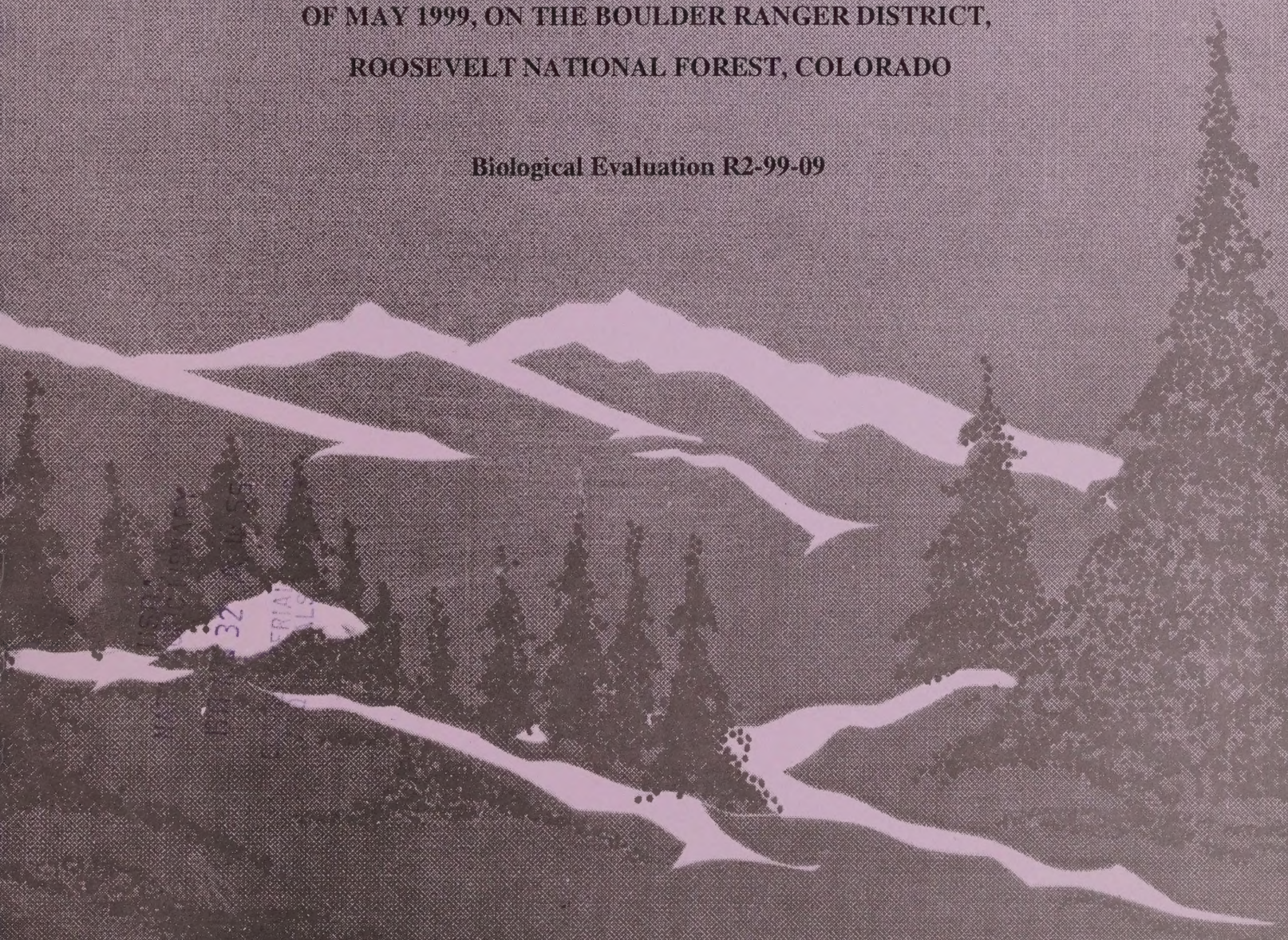
Forest Health Management

EVALUATION OF THE MOUNTAIN PINE BEETLE AT THE SITE OF THE JAMESTOWN PRESCRIBED FIRE OF MAY 1999, ON THE BOULDER RANGER DISTRICT, ROOSEVELT NATIONAL FOREST, COLORADO

Biological Evaluation R2-99-09



USDA United States Department of Agriculture

Renewable Resources
Forest Health Management

Forest Service
Rocky Mountain Region
Denver, Colorado

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Biological Evaluation R2-99-09

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MAY 1999

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ABSTRACT

The mountain pine beetle (MPB) was found to be attacking pines in the area burned by the Jamestown prescribed fire of May 1998. Aerial surveys in 1996, 1997, 1998, and ground surveys in the fall of 1998, showed that killing of pines by MPB had been taking place in and around the area affected by the fire for several years prior to the fire and that tree killing was increasing. The amount of tree killing was found to be within recognized limits for rising MPB populations without regard for fire effects. The number and density of unsuccessful attacks by MPB in the area affected by the fire was greater than expected for rising MPB populations and may have been influenced by fire impacts. MPB action alternatives, specific recommendations, and implementation activities are described. A resurvey in the spring of 1999 showed that the results of MPB attacks are easier to interpret after the winter. Ideas for developing case histories on MPB - prescribed fire interactions are presented, for we currently have little information on this subject. Implications for future prescribed burning in the presence of active tree killing bark beetle populations are presented, along with a list of public involvement in this case.

ACKNOWLEDGMENTS

Excellent field assistance from Bob Alm, Jennifer Chase, Lisa Dann, Dave Johnson, Erik Johnson, Susan Johnson, and Paul Mintier was essential and greatly appreciated.

INTRODUCTION

This evaluation concerns mountain pine beetle [MPB], *Dendroctonus ponderosae* Hopkins (Order Coleoptera; Family Scolytidae), activity in and around the area of the Jamestown prescribed fire of May 4, 1998, in north-central Colorado in Township 2 North, Range 72 West, Section 25 and Township 2 North, Range 71 West, Section 30. The results of MPB surveys are presented and discussed in relation to the fire. Alternative actions available against MPB are described in conjunction with predictions of the likely outcomes of each action. Forest Health Management's role in the implementation of the selected action alternative is described. Contacts with the concerned public and government agencies over this matter are listed. Suggestions for future prescribed fires in the vicinity of MPB activity are presented. This evaluation begins with a description of recent MPB activity in the Jamestown area in the context of the Front Range and the current overall MPB situation in Colorado.

Mountain Pine Beetle Conditions

The mountain pine beetle (MPB) is a native, tree-killing bark beetle that for millennia has played an important role in pine forest ecology. MPB populations are ubiquitous throughout western pine forests, where they persist at low, endemic levels. Few, if any, pines are mass attacked, colonized, and killed by endemic MPB populations. Within susceptible stands, in response to conditions that are not fully understood, these endemic MPB populations regularly increase to high, epidemic levels. Many pines are mass attacked, colonized, and killed by epidemic MPB populations. MPB epidemics do not require a

triggering landscape disturbance, such as fire or windthrow, to be initiated and MPB epidemics can spread. According to our records since 1900, there has been at least one MPB epidemic somewhere along the Front Range during each decade, except the 1980s.

Beginning at low levels in 1995, mortality of pine caused by MPB has increased in Colorado each subsequent year. Aerial survey results, each year covering most of Colorado's forested acres, estimate the total number of pines killed statewide by MPB as follows: 12,891 in 1996; 32,445 in 1997; and 74,288 in 1998. Some areas of Colorado now have extensive, concentrated pine mortality. Currently, affected areas are at both low and high elevations in lodgepole, limber, and ponderosa pines, ranging from the Black Forest in the plains to the high elevation valleys of Vail, the upper Arkansas, and Colorado Rivers. It is expected that this increase in MPB-caused mortality will continue for several years, unless unusual weather conditions intervene. This is because significant portions of pine forest statewide are highly susceptible to MPB, being mature and densely stocked.

MPB has a life cycle that is one year long on the Front Range. Because the foliage of newly attacked trees remains green for many months, successfully colonized pines appear unaffected from a distance. It is important to remember throughout this evaluation that, with rare exception, successfully colonized pines cannot be detected from a distance until the spring or summer following MPB attack. That is the time when the foliage on successfully colonized pines fades in color from green, to yellow, to red. Only close inspection from the ground can detect currently infested pines whose needles are still green. Therefore, aerial detection surveys show the results of MPB activity during the prior summer. For example, the 1996 aerial survey describes the outcome of MPB attacks which occurred in 1995.

Aerial survey sketch maps showed that MPB activity overall on the Roosevelt National Forest was low in 1996. On the Forest along the Front Range, concentrated MPB activity was reported in the Cache la Poudre Canyon and Red Feather Lakes areas. This was mentioned in the February 3, 1997, report to the Forest from Forest Health Management (Report LSC-97-07, "Forest Health Aerial Survey of the Roosevelt NF," file designation code 3410), which presented the results of the 1996 aerial survey conducted by Erik Johnson, Biological Technician, Lakewood Service Center, and myself.

By the next year, MPB activity had increased somewhat on the Roosevelt National Forest, according to the 1997 aerial survey. The 1997 survey results were presented to the Forest in our November 24, 1997, report (Report LSC-98-06, "Aerial Survey of the Roosevelt NF," file designation code 3410) from Forest Health Management.

Two new areas of MPB activity in 1997 on the Roosevelt National Forest along the Front Range were mentioned in that report. One was described as being "on both sides of Four Mile Creek west of Boulder, running north to Jamestown (T.1 N, R. 71 & 72 and T.2N, R.71 & 72)." Although only two MPB-killed trees were mapped in that area in the 1996 aerial survey, a total of 236 trees on 217 acres was detected in 1997. The 1997 aerial survey map shows six MPB-killed ponderosa pine in three polygons in the immediate vicinity of Jamestown --- one just west of, one just north of, and one inside of the area of the Jamestown prescribed fire.

The 1998 aerial survey, shows that the Front Range experienced a dramatic increase in MPB-caused pine mortality. An estimated total of 11,602 pines faded and were sketch mapped in the Front Range counties of Boulder, Clear Creek, Douglas, Elbert, El Paso, Gilpin, Jefferson, Larimer, Park, and Teller. Within the large area from Jamestown south to Highway 285, an estimated 2,492 ponderosa pines were killed in 1998 by MPB. Results from Boulder County have been compiled separately, showing that the trend was

again upward for MPB activity. The actual number of faded ponderosa pines killed by MPB that were detected and sketch-mapped in Boulder County, increased from 348 in 1997 to 990 in 1998. This 2- to 3-fold increase is consistent with what I have observed on-the-ground.

As data presented later in this evaluation will show, it is highly likely that MPB attacks detected in the vicinity of Jamestown from the ground in 1998 on as yet still green pines will lead to an aerial survey report in 1999 showing another increase, in the absence of any treatment that removes green infested pines. Some older areas of MPB activity will have expanded and newer areas will have appeared. It must be stressed that the current outbreak is much smaller at present than the extensive, extreme levels of MPB-caused mortality which occurred in the late 1970s on the Roosevelt National Forest along the Front Range. However, significant local MPB activity is occurring and increasing.

State of Knowledge: MPB and Fire

In the spring of 1998, I received a telephone call from Paul Mintier, Fuels Specialist for the USDA Forest Service, Boulder Ranger District. Aware of the MPB situation, Paul was concerned about the potential for unanticipated impacts from MPB at the site of several proposed prescribed fires, including at Jamestown. Unfortunately, I was not available to visit or to survey the Jamestown area prior to the prescribed fire, contrary to Paul's request for such service. He also asked for information on the relationship between MPB and fire.

I told him that few firm facts were available on the topic of MPB and fire. The current consensus among western forest entomologists is that MPB epidemics are not initiated by fires. MPB has been documented infrequently as having responded to fires by attacking and killing fire-weakened pines. These reports seem reasonable, because MPB will focus their attacks on pines weakened by a variety of influences, including root disease and dwarf mistletoe infection, lightning, and top injury (Eckberg *et al.* 1994). I told Paul that, in my experience, MPB will usually colonize very few of the burned pines in an area and that these attacked trees will have been neither burned heavily, nor entirely unaffected by the fire. To become especially attractive, a burned pine needs to incur a specific, as yet undetermined, type of fire injury. To become colonized and killed, this tree must be in an area where MPB is at elevated population levels prior to the fire. The current state of our knowledge does not allow reasonable prediction of the response of MPB to fires. I summarized my discussion with Paul by saying that burning would not start any MPB problems, but that conditions might become more favorable for the beetles as a result of the "right sort of fire."

Request for Assistance

At the beginning of September 1998, I began to receive reports that the Jamestown prescribed fire area had many new MPB attacks. These new attacks were not preexisting, meaning that they had occurred after the fire as a result of the MPB flight in late summer, 1998. Some of these reports were quite dramatic and apparently based upon a subsample of the acreage affected by the fire. On September 8, 1998, I accompanied a large interagency group on a field trip to the site of the Jamestown prescribed fire. It was clear that some of the earlier reports had overestimated the amount of MPB activity. It was also obvious that the MPB activity in the vicinity was significant and that many pines within the burned area had been attacked. At the request of the Boulder Ranger District, I undertook to evaluate the area affected by the prescribed fire and some of the general vicinity with respect to MPB activity. I also explained my findings to concerned individuals and organizations.

[illegible]

State of Knowledge: MPB and [illegible]

[illegible]

Request for Assistance

[illegible]

METHODS

Within the area burned by the Jamestown prescribed fire, all ponderosa pine of a diameter equal to or greater than 6 inches at breast height were examined from the ground for any evidence of attack by MPB. Each pine was classified as attacked or not attacked by MPB, regardless of the number of attack sites detected. The minimum diameter, six inches, is at the lower limit for colonization by MPB. The bark of any pine suspected of having been attacked by MPB was chopped with a hatchet at up to three areas around the circumference and the phloem (inner bark) and sapwood examined. The presence of MPB larvae (immature, developing beetles) or larval tunnels in the phloem and/or evidence of colonization of the sapwood by blue stain fungi carried by MPB, were considered to be evidence of successful colonization. We further classified the attacked pine according to the year of MPB attack (1998, 1997, or Older Attacks). As years pass, it is increasingly difficult to date when a pine was attacked by MPB. This is why the category "Older Attacks" was created. Pines in this category were killed by MPB in the last five years or so and do not include very old snags. For pines attacked in 1998, we determined if the attack was successful (e.g. 1998 Kills, Table 1), meaning, that MPB colonized the tree and would reproduce within that tree and yield adult MPB in 1999; or if the attack was not successful (e.g. 1998 Pitchouts, Table 1) meaning, that it was most likely that the tree was not colonized and would not produce MPB in 1999. At the time of the surveys, it was not possible to discern the full impact of the prescribed fire on trees, so that pines which were classified as "Not Attacked" may die from causes other than MPB.

The burn area and vicinity was surveyed in the fall, after MPB attacks had ceased for 1998. The burn area was resurveyed in the spring, when the impacts of winter and woodpeckers on the MPB population was evident, and when the outcome of the 1998 MPB attacks on individual pines could be more accurately determined.

Variations in survey methods are noted as appropriate in the sections which follow.

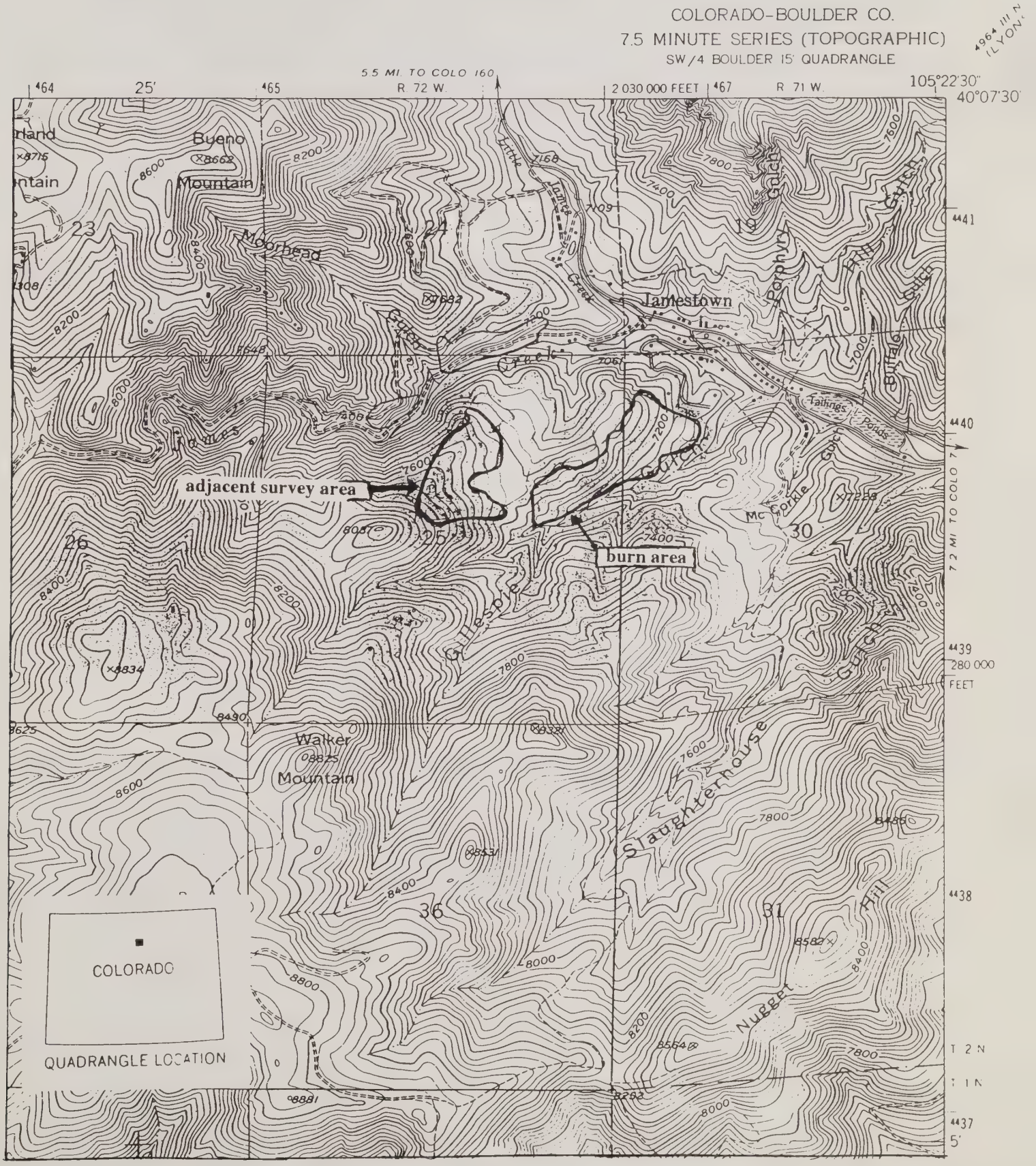
RESULTS AND FINDINGS

Forest Conditions

The burned area and adjacent lands to the west are public property, administered by the USDA Forest Service, Roosevelt National Forest, Boulder Ranger District. Somewhere just east of a barbed wire fence, near the eastern edge of the burn, is the boundary between public and private property.

The 43-acre area burned by the Jamestown prescribed fire is on a south-to-southeast facing slope that ranges from about 7,160 to 7,440 feet in elevation (Figure 1). The area extends uphill from a creek bottom, with slopes ranging from 5 to 45 percent, approximately. The northern boundary is an open ridge top that extends from southwest to northeast, and which terminates near the northeastern boundary of the fire. The eastern boundary is close to several private residences, with a main dirt road beyond the houses. The southern boundary is Gillespie Gulch, which has a small creek in the bottom.

Figure 1. Approximate location of the Jamestown, Colorado, prescribed fire of May, 1998, and the adjacent area surveyed for mountain pine beetle activity in September, 1998.



The western boundary is a four-wheel drive dirt road. Trees occupy almost all of the area, though there are a few openings and a small meadow in the southwestern corner. Canopy closure and tree density vary considerably, although most of the area has a fairly closed canopy of sawtimber-sized trees. Trees are almost exclusively mature ponderosa pine, *Pinus ponderosa* var. *scopulorum* Dougl. ex Laws., with some smaller Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, especially at the bottom of the slope, and a few juniper, *Juniperus* spp.. Many of the pines are lightly infected by dwarf mistletoe, *Arceuthobium vaginatum* subspecies *cryptopodum,* which is most prevalent in the western third of the burned area and along the ridge top. Overall area averages, based upon some variable radius plots and ocular estimates, is that the basal area would be in the range of 100 - 120 square feet per acre, and the average tree diameter greater than or equal to 8 inches. The general absence of stumps and relatively low frequency of younger, smaller pines indicates that this forest has not been subject to disturbances such as logging or fire since the establishment of the current generation of mature trees. The relatively homogenous, large size of the pines suggests that this area regenerated as a unit sometime in the latter half of the 19th century.

The north-facing slope to the south of the area burned by the Jamestown prescribed fire, across Gillespie Gulch, is dominated by Douglas-fir and shows little or no evidence of current MPB activity. The area to the north is a mixed ponderosa pine - Douglas-fir forest that continues downhill into Jamestown. The area to the northwest has a large, oblong opening of about 30 acres and an adjacent area of smaller pines heavily infected by dwarf mistletoe, with evidence of current and prior MPB activity. The area to the west is a mixed forest of ponderosa pine, Douglas-fir, juniper, and aspen, *Populus tremuloides* Michx., with scattered clumps of dense, large pine showing evidence of current and prior MPB activity.

The Prescribed Fire

The objective of the Jamestown prescribed fire was to conduct an understory burn that would lower the fuel load, which in turn would lower the intensity and severity of any future wildland fire in the area. The immediate proximity of Jamestown and private residences was a major consideration. A target of overstory tree mortality was set at a maximum of 20%, which was intended to retain larger trees while widening the spacing of tree crowns to reduce the potential for any future wildfire to attain and move through the tree crowns. In preparation for the burn, lower tree branches were pruned and left on the ground. This step was intended to reduce ladder fuels and the possibility that the burn would move up into the tree crowns. The burn plan is on file at the USDA Forest Service, Boulder Ranger District office.

It appeared that the overstory tree mortality target was not exceeded by the impact of the burn, although it will be some years before this can be measured. Many pines were scorched at the base and quite a few incurred some lower crown scorching. Along and just below the ridge top in the steeper sections, a number of trees were severely burned, especially in the northeastern portion of the area. Some of the pruned branches on the ground were not consumed by the fire. As expected, the Douglas-fir, mostly younger smaller trees, were more severely affected by the burn than the pine.

MPB Survey of Burn Area, September 1998

On September 23, 29, and 30, 1998, the entire Jamestown prescribed fire area was surveyed for MPB activity. Assisting me were Erik Johnson and Lisa Dann (Biological Technicians, Lakewood Service Center, Forest Health Management) and Susan Johnson (Biologist, Regional Office, Forest Health Management). The easily identified fire lines and roads were used as survey boundaries, enclosing the 43-acre parcel that was actually subject to the prescribed fire. We blazed trees lightly with a hatchet in order to avoid counting trees more than once, and proceeded across the slope in a series of swaths until the entire 43 acres had been systematically examined. A field map was made that indicated the approximate location of each swath and the presence of heavily infested pines. Although collected by swath, the data are presented in summary below (Table 1). All original records are on file at the Lakewood Service Center.

Table 1. Survey of mountain pine beetle (*Dendroctonus ponderosae*) attacks on ponderosa pine trees on the 43 acres affected by the Jamestown, Colorado, prescribed fire of May 4, 1998, completed on September 23, 29, and 30, 1998, by USDA Forest Service, Forest Health Management.

NOT ATTACKED	ATTACKED After the Fire 1998 KILLS	ATTACKED After the Fire 1998 PITCHOUTS	ATTACKED Before the Fire 1997 ATTACKS	ATTACKED Before the Fire OLDER ATTACKS	TOTAL TREES
3,530	41	170	18	8	3,767
93.7%	1.1%	4.5%	0.5%	0.2%	100%

Column Explanations:
NOT ATTACKED - All pines, regardless of status, alive at the time of the fire, but not attacked by mountain pine beetle
1998 KILLS - Pines successfully colonized and killed by mountain pine beetle in 1998
1998 PITCHOUT - Pines attacked but not successfully colonized by mountain pine beetle in 1998
1997 ATTACKS - Pines attacked by mountain pine beetle in 1997, regardless of relative success of attack
OLDER ATTACKS - Pines attacked and killed by mountain pine beetle before 1997 but within about the past 5 years
TOTAL TREES - All pines in the fire area greater than or equal to six inches in diameter at breast height

In the area burned by the prescribed fire, the two most important findings are that MPB had been active for several years prior to the fire, and that about two hundred pines were attacked in 1998 by MPB.

Pines classified as "1998 Kills" are often called "green hits," because their needles remain green and do not fade to the yellow and reddish colors characteristic of MPB-caused death until summer 1999. These "1998 Kills" are expected to produce MPB in 1999 that can attack additional pines. The spatial pattern of "1998 Kills" suggested that some MPB immigrated into the burned stand from the North and the West. Thirty-six "1998 Kills" were either in the western third of the stand, between the boundary road and the secondary road east of it which bisects the stand, or along the ridge top which forms the northern boundary. The remaining five "1998 Kills" were located in the southeastern portion of the burned stand, and may have been colonized primarily by MPB that were produced within the stand from the "1997 Attacks."

A "1998 Pitchout," as described above, is a tree attacked one or more times by MPB during 1998, but which appeared to resist MPB colonization. Many of the pitch tubes on such a tree were white and runny, indicating that the beetle which entered the tree at that point was drowned in pitch before reaching the reddish colored phloem. However, some of the pitch tubes on a "1998 Pitchout" were reddish, coherent, and peg-like, indicating a point where a beetle successfully bored into the phloem. Some of the "1998 Pitchout" trees had a surprisingly large number of pitch tubes, despite the lack of evidence of successful colonization. I suspect that fire injury played some role, such that trees which appeared to be attacked by enough MPB to lead to successful colonization had, in fact, resisted attack and will survive.

In two "1998 Pitchout" trees, unhatched, turgid, apparently fresh MPB eggs were found under the bark, adjacent to a live parent adult beetle in its egg gallery. It is known that bluestain fungi can take several weeks to colonize the sapwood sufficiently to be observed. Because of the presence of eggs and the delay in bluestain colonization, it may be that some of these "1998 Pitchout" trees were, in fact, successfully colonized and will die, producing some MPB. Experience and past history would indicate that MPB flight and attack had ceased before the survey, which was deliberately conducted at the end of September for this reason. Yet, it seems that in two cases at least, egg hatch of MPB under the bark was not completed by late September.

It was clear that MPB had been active in the stand burned by the prescribed fire prior to the fire. Pitch tubes exposed to fire take on a characteristic color and texture that is diagnostic. An examination of the inner bark provided further confirmation. Therefore, pines classified as "1997 Hits" were green and may have been infested by MPB when the prescribed fire occurred. The category of "1997 Hits" combined those pines successfully colonized (i.e "Kills") with those which resisted MPB colonization (i.e. "Pitchouts").

There were at least five pines that were attacked, but resisted colonization by MPB both in 1997 and 1998. These were arbitrarily classified as "1998 Pitchouts," but should be considered as belonging to both categories. Each of these five pines that resisted MPB colonization in both 1997 and 1998, were located immediately adjacent to a "1998 Kill."

MPB Survey adjacent to the Burn Area, September 1998

On October 27, 1998, Lisa Dann and I returned to the area to investigate MPB activity in the vicinity of the Jamestown prescribed fire area. We went uphill and west of the burn until the tree cover ended and then backtracked into the forest, where we worked our way back down toward the burn area. We used the same diagnostic techniques and survey methods as before, with the exception that we did not tally uninfested trees and did not explicitly cover swaths of ground. By working in tandem, we avoided double counting trees attacked by MPB. We found three pockets of MPB activity close together, located west and northwest of the northwestern edge of the burn across an opening in the forest. This area of MPB activity appears on the 1997 aerial survey map, accurately drawn where it is located on the ground. The nearest pine recently killed by MPB was 400 - 500 yards uphill to the west and across the opening from the burn perimeter; the farthest pine recently killed by MPB which we identified was 100 - 200 yards further uphill to the west. At a point approximately north of the western burn perimeter on the steep, north-facing slope where the forest becomes mostly Douglas-fir, our survey activity was ended.

Scattered, isolated pines and small groups of pines killed by MPB could be seen downslope north of the burn continuing all the way north into the Jamestown vicinity. Our findings, presented in Table 2, reinforce the observations made within the burned area that MPB has been killing pines in the Jamestown area for several years prior to the Jamestown prescribed fire.

Table 2. Survey of mountain pine beetle (*Dendroctonus ponderosae*) activity in selected areas west and northwest of the Jamestown, Colorado, prescribed fire of May 4, 1998, completed on October 27, 1998, by USDA Forest Service, Forest Health Management.

NOT INFESTED	1998 KILLS	1998 PITCHOUTS	1997 ATTACKS **	OLDER ATTACKS	TOTAL TREES
NA *	4	4	8	29	NA *

* Not Applicable

** Unlike the results in Table 1, all "1997 Attacks" were successful colonizations leading to tree death and none were pitchouts.

The Selected Action

The various action alternatives available against MPB are summarized in Appendix 1 and discussed in Appendix 2. Action Alternative 4, Infested Tree Treatment, was the alternative selected by the Boulder Ranger District, USDA Forest Service, following input from the public, the Jamestown MPB Task Force, the Jamestown Town Board, the Colorado State Forest Service, and me, including a draft version of this evaluation dated February 25, 1999. It was decided to treat "1998 KILLS" and "1998 PITCHOUTS" (Table 1), as recommended under Alternative 4 in the "Predictions and Recommendations for the Jamestown Area" section (Appendix 2).

MPB Resurvey and Tree Marking, March 1999

To begin to implement the selected action, the stand affected by the fire was resurveyed and marked on March 16, 1999, by me, Dave Johnson (USDA Forest Service, Forest Health Management, Lakewood Service Center), Jennifer Chase, and Bob Alm (Colorado State Forest Service, Boulder District). Pines attacked by MPB in 1998 were relocated and sprayed with tree marking paint on two sides. Successfully colonized trees (i.e. "1998 KILLS") received a "X" paint mark and unsuccessfully colonized trees attacked by MPB (i.e. "1998 PITCHOUTS") received a solid "0" paint mark. At the end of the day, we had marked 79 trees with a "X," and 62 trees with an "0." The general location of successfully colonized trees marked with a "X," was mapped, just as in the fall survey.

The only change in methods was that pines with a minor level of MPB attack were not marked, because they do not present a significantly enhanced target in 1999 for additional MPB attack. So few attacks were made on these trees, that they are presumed to be no more attractive than previously unattacked pines. A minor level of MPB attack was defined as four, later reduced to three or fewer attacks, all of which were unsuccessful as evidenced by larger, whiter, runnier pitchtubes. Leaving these minor

pitchouts unmarked and untreated, would reduce the effort required to treat the burn area without affecting the efficacy of the treatment. It should be remembered that 1998 pitchouts present no hazard of contagion, because they will not produce MPB in 1999. Pitchouts were recommended for removal only because (a) my experience and some literature (Eckberg *et al.* 1994) indicate that previously attacked pines are somewhat more likely to serve as focus trees for MPB in subsequent years, as compared to unattacked trees (see Alternative 4 under the section "Predictions and Recommendations for the Jamestown Area" in Appendix 2); and (b) I had been informed that MPB treatment within the prescribed fire area would occur just once, in 1999, and not in subsequent years.

On March 19, I revisited the site with Paul Mintier to host a walk-through and discussion of the selected action. Two members of the Jamestown MPB Task Force participated in the walk-through and discussion of the selected action. In addition, a resident whose home is at the eastern edge of the stand met us, and briefly discussed the MPB situation and the selected action as we traversed the area. On that day, we found and added three colonized "X" trees and two pitchout "0" trees while walking through a portion of the stand.

Because at least two of these colonized trees were so obvious that they should not have been missed, a second complete cruise was conducted by me and Paul Mintier on March 22, 1999. This cruise resulted in the paint from two "0" trees being removed, one "0" tree being changed to an "X," and two "0" trees and three "X" trees being added. The final results are presented in Table 3.

Table 3. Results of the survey to locate and paint mark ponderosa pine trees attacked in 1998 by mountain pine beetle (*Dendroctonus ponderosae*) on the 43 acres affected by the Jamestown, Colorado, prescribed fire of May 4, 1998; survey and marking conducted jointly on March 16, 19, and 22, 1999, by USDA Forest Service and the Colorado State Forest Service.

NOT ATTACKED	ATTACKED After the Fire	ATTACKED After the Fire	ATTACKED Before the Fire	ATTACKED Before the Fire	TOTAL TREES MARKED
	1998 KILLS	1998 PITCHOUTS	1997 ATTACKS	OLDER ATTACKS	
NA *	85	65	NA *	NA *	150
	trees painted with "X"	trees painted with "0"			

* Not Applicable

Column Explanations:

NOT ATTACKED - All pines, regardless of status, alive at the time of the fire, but not attacked by mountain pine beetle

1998 KILLS - Pines successfully colonized and killed by mountain pine beetle in 1998

1998 PITCHOUT - Pines attacked, but not successfully colonized by mountain pine beetle in 1998

1997 ATTACKS - Pines attacked by mountain pine beetle in 1997, regardless of relative success of attack

OLDER ATTACKS - Pines attacked and killed by mountain pine beetle before 1997, but within about the past 5 years

TOTAL TREES MARKED- All pines in the fire area to be treated, marked with tree paint

It was evident from the March 1999 resurvey and tree marking, that the results acquired in the fall had changed. This was expected. With the passage of time, the consequences of MPB attacks are increasingly easy to determine.

The full effect of many factors, including survival of MPB larvae and bluestain fungi under the bark and the effects of temperature and tree resistance on the developing MPB population, is more apparent in the spring than it is in late summer just after the MPB attack period.

Comparing the September 1998 survey (Table 1) with the March 1999 resurvey (Table 3), the number of successfully colonized pines ("1998 Kills") roughly doubled. Therefore, about one quarter of the pines classified as pitchouts in the fall were revealed in the spring as having been successfully colonized by MPB. This explains why the number of successfully colonized trees increased in the resurvey.

The location of successfully colonized pines was virtually identical in both surveys. The major difference is that more attacked pines were classified as having been successfully colonized in a given location during the spring resurvey. No new group of successfully colonized pines was located in the spring resurvey. The approximate location of successfully colonized trees is presented in Figure 2. I am confident that successfully colonized trees ("1998 Kills") were located and marked during the resurvey.

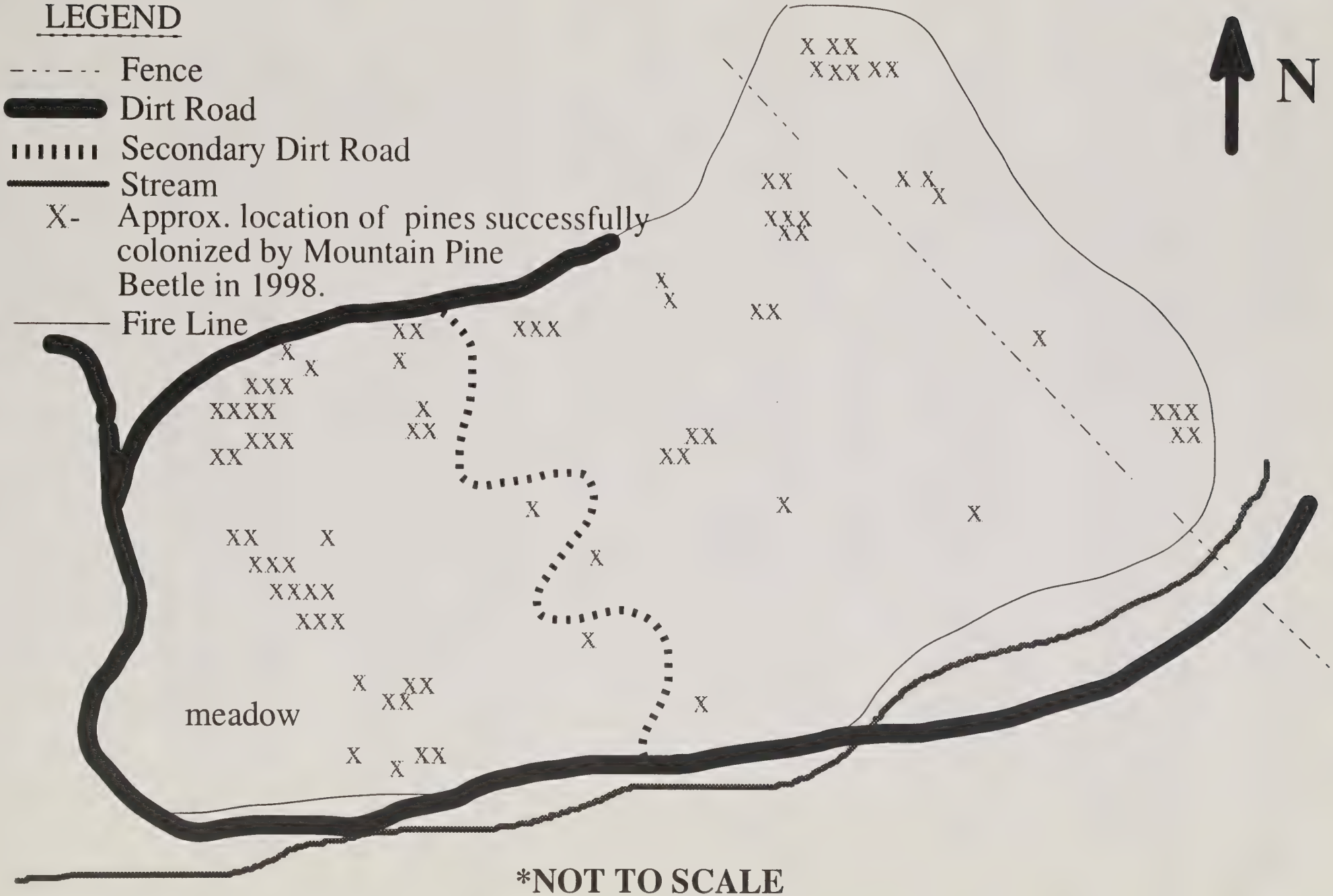
The number of attacked pines that were not successfully colonized ("1998 Pitchouts") was reduced by a bit more than half in the resurvey (Table 1 versus Table 3). There are a number of causes for this reduction. One is the change in methods for the resurvey, not marking or counting minor, unsuccessful MPB attacks. Another, is that evidence of minor attacks on some pines was concealed or removed by wind and weather over the winter. Some trees severely injured by fire and also attacked by MPB had begun to rot by the spring, could not serve as an MPB host tree, and were classified as fire victims instead of pitchouts in the resurvey. And some MPB attacks were probably missed in the resurvey, due to the differences in the survey efforts. The survey effort in the fall utilized more people over a longer time and was intended to detect every MPB attacked tree, including those with only one runny white pitch tube way up the trunk. The resurvey effort utilized fewer people over a shorter time, and was intended to confirm the results of the earlier survey and to locate and mark the more heavily attacked and/or colonized pines.

DISCUSSION

Forest Conditions

Many areas in the stand burned in the Jamestown prescribed fire are what western forest entomologists call "beetle bait." This is a term used to describe a stand or area within a stand that is in a condition that is ripe for attack and mortality from MPB, a condition characterized by a relatively large diameter of pine and a relatively high density and close spacing of large pine. "Beetle bait" areas are more likely to be attacked initially by MPB and to have a greater level of MPB-caused mortality if an epidemic develops and runs its course. My overall estimate from variable radius plots measured with a 10-factor BAF prism and a general impression is that, in many portions of the stand, the basal area is greater than or equal to 100 square feet and the average pine diameter exceeds 8 inches. Average diameter, density, and spacing of ponderosa pine in a stand can be used in a qualitative assessment of the concentration and quantity of "beetle food" that the stand contains. These parameters have been used to rate stands for the hazard of initial MPB attack in relatively homogenous, even-aged ponderosa pine stands in the Black Hills (Schmid *et al.* 1994). Schmid *et al.* (1994) suggest that their rating method may be applicable in other parts of the range of ponderosa pine. The literature on the subject shows that stand parameters, such as those mentioned, have been associated with the level of MPB activity, given an active MPB population.

Fig. 2: Infested Pines in Jamestown Prescribed Fire Area, 1998*



*NOT TO SCALE

The results presented here show that MPB has been active in the area, killing pines, for several years. There is clear evidence, both within the area affected by the fire and adjacent to it, of a growing level of MPB activity.

In light of the elevated level of MPB activity nearby, it is not surprising that MPB would immigrate into the nearest and best source of food, that is, into the area burned by the prescribed fire, whether it had been ignited or not. In fact, the stands uphill and west of the burned area had recently been depleted of susceptible pines by MPB, especially where they were growing in dense clumps. MPB dispersal from areas where suitable hosts are depleted into nearby areas would be expected in an increasing MPB population.

The increased level of MPB-caused mortality, as measured by the "1998 Kills" (Table 3), is consistent with the rising amount of MPB activity in the vicinity of Jamestown and along the Front Range. From Tables 1, 2, and 3, it appears that the number of pines killed by MPB in the general vicinity of the Jamestown prescribed fire roughly doubled or tripled from 1997 to 1998. Such an increase is well within expected parameters for an increasing, healthy MPB population without regard for fire effects.

The Prescribed Fire and MPB

Having stated that the level of MPB mortality in the area is within expected levels and having described the highly susceptible condition of the burned area in the absence of fire, it does appear that the prescribed fire in some way affected MPB behavior. The very large number of unsuccessful attacks ("1998 Pitchouts," Table 1) is unusual in my experience for building MPB populations, even when discounted by the facts that about 40 of these were actually successful attacks ("1998 Kills," Table 3); at least 5 were also 1997 attacks (Table 1); and that some were attacks on pines severely injured by fire which could not support MPB development. A few pines had been attacked so many times that it was very difficult to accept that they had not been successfully colonized. This spring, I chopped into some of these unsuccessfully attacked trees at many of the attack sites, even climbing up into a few of them to do this, and verified that the numerous MPB attacks had not resulted in colonization.

It is as if the beetles did not apportion their numbers in a way that would maximize the number of successfully colonized pines and spread themselves too thinly among trees. It could be that fire injury to some of the pines in some way presented a signal to MPB that the trees had been weakened far more than was the case. Quite clearly, many pines mounted a defense that overwhelmed significant numbers of attacking MPB. A less likely speculation, is that perhaps the trees, once attacked, were determined to be somehow undesirable as hosts and few or no eggs were laid. Whatever the cause and effect relationship, we documented many more pitchouts than would be expected from the admittedly small area we surveyed. It is difficult to accept that this large number of 1998 pitchouts is not in some way related to the prescribed fire.

I do not know how fire injury affects the nutritional quality of pine phloem for MPB. My qualitative assessment of the developing MPB brood is that few of the colonized pines seemed densely inhabited. Whether this is a function of food quality, attack density, or other factors is not known. The collaboration of a fire ecologist would be very helpful in investigating future incidents such as this. Measurement of the degree of fire injury to individual pines would greatly help in interpreting MPB behavior.

[illegible]

[illegible] transportation.

The [illegible] level of MPP [illegible] was measured by the "[illegible]" [illegible] with the [illegible] Tables [illegible] appears that the [illegible] in the general [illegible] without regard for [illegible].

The [illegible] of MPP

Finally, [illegible] the [illegible] MPP [illegible]

[illegible]

[illegible] MPP [illegible]

Many of the ponderosa pine we examined were heavily infected by dwarf mistletoe. Research along the Front Range has shown that mistletoe-infected ponderosa pines were slightly more attractive to MPB than uninfected pines (Johnson *et al.* 1976), in agreement with the conclusions reached by McCambridge *et al.* (1982) in their MPB impact study conducted in north-central Colorado. Dwarf mistletoe infection was more intense and widespread among the pines in the area to the north of the burned stand. These shorter, presumably slower growing, and stressed mistletoe-infected pines present MPB with a reservoir of attractive hosts which may be less able to defend themselves from colonization. Virtually every pine in this area that was killed by MPB or *Ips* species, was heavily infected by dwarf mistletoe. To focus stand management only on MPB and then only when it is at elevated levels, is to consider only a part of the story. Mortality of pines from MPB is a symptom of stand and tree conditions, some of which can be manipulated to the disadvantage of MPB. Such a proactive approach, however, may be beyond the budget and priorities of land managers, private or public, in all but a few circumstances. And mortality of pines from MPB can never be completely halted.

Implications for Future Prescribed Fires and MPB

Increasingly, land managers are recognizing the ecological value of fire and seeking to reintroduce it into ponderosa pine forests with prescribed burns. As we have little existing knowledge on the interaction of fire impacts and MPB behavior, it is important to document incidents in order to develop a set of case histories. Hopefully, some patterns will emerge from such efforts. Experimental manipulations in the field would be very complex to conduct, as the "beetle pressure" in an area is difficult to quantify, and nearly impossible to replicate. So it is a case history approach that will have to suffice for now.

The following is a tentative set of recommendations regarding prescribed fire in the ponderosa pine - Douglas-fir forest types along the Colorado Front Range where there are active populations of either MPB or Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae*, in the immediate vicinity, based, in part, on the Jamestown prescribe fire experience:

1. Survey the area in the vicinity and the stand to be burned well before the fire.

Should there be significant levels of recent tree mortality, contact Forest Health Management staff and request a more formal survey. While the response of tree-killing bark beetles to a burn may not be predictable yet, such baseline information will facilitate a reasoned interpretation of what transpires and will help develop additional case histories.

2. Try not to burn in the spring.

This precaution is to allow fire-injured trees the maximum time to recover before they are challenged by MPB or DFB. If there is no bark beetle activity in the area or if some bark beetle-caused mortality is acceptable, this precaution is not important. Additional considerations, such as the response of noxious weeds, may override concern about bark beetles.

3. Include the potential for MPB and DFB impact when creating mortality targets for fire prescriptions.

We know that there are many forest insects that interact with the fire effects on trees. Many of these agents are associated with mortality of fire injured trees, but their impacts may be attributed to direct fire effects. The added involvement of MPB and DFB, however, can lead to mortality of trees not injured by fire both in the burned area and adjacent to it.

4. Watch out for Douglas-fir beetle!

DFB is well-known as a tree killing bark beetle that will often, but not always, respond dramatically in fire injured stands. DFB will first infest burned and then scorched Douglas-fir and then can move into nearby unburned green stands and decimate them. This has been observed by me following the Clover Mist Fire of 1988 in Wyoming, and as a result of the Buffalo Creek Fire of 1996 in Colorado. While both were wild fires, other incidents in Colorado have been noted following prescribed fires where unanticipated mortality from DFB took place. Casual observations in the Jamestown prescribed fire area show that most, if not all, of the fire affected Douglas-fir were killed by insects. However, these insects are probably not DFB, as the trees are too small. DFB, like MPB, attacks trees larger than about six inches in diameter at breast height. Unlike MPB in ponderosa pine, DFB preferentially attacks the larger host trees available.

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Appendix 1: Action Alternatives against MPB

Following the fall surveys, the full range of possible actions available against MPB were presented to the various concerned groups and individuals, including USDA Forest Service personnel. The following is a summary of those action alternatives.

Alternative 1: Do Nothing - Accept pine tree mortality and associated impacts caused by MPB as a natural phenomenon. MPB is a native insect that coevolved with pine forests. It is one of the most important biotic causes of pine mortality in conifer forests across the West. MPB populations increase and decrease without direct human influence. Epidemics of MPB have many ramifications in addition to the creation of dead pine trees. These impacts vary, depending upon the extent, intensity, and duration of the MPB epidemic.

Alternative 2: Silvicultural Treatment - Actions which promote tree vigor and wide spacing are the primary means to reduce or prevent the impact of MPB epidemics. The best long-term tactic to minimize losses to MPB is to partially cut susceptible stands, or harvest and subsequently replace susceptible stands. Removal of individual pines of low vigor and poor health will lessen the chance that MPB may get started in an area. Highly hazardous conditions for MPB in ponderosa pine stands are those where average tree diameter is equal to or greater than 8 inches, and basal area is greater than or equal to 120 square feet. Therefore, partial cutting that reduces stands to 60-80 square feet of basal area or less, and average tree diameter to below 8 inches affords the greatest protection. When partially cutting (thinning) susceptible stands, care must be taken to avoid leaving dense pockets of mature pines and trees heavily infected by dwarf mistletoe, because these areas can serve as foci for MPB attack. Cutting trees already killed by MPB is called "salvage harvesting" and is discussed under Alternative 3.

Alternative 3: Sanitation/Salvage Harvesting - Sanitation harvesting is a treatment applied to currently infested pine stands. Green trees with immature MPB developing under the bark are cut and either removed to an area at least one mile from other, susceptible pines or processed at a mill prior to MPB emergence. This makes it impossible for the MPB living within the infested trees to mature, emerge, and attack uninfested pines. MPB emergence can begin as early as mid-July; sanitation must be completed prior to MPB emergence to be effective. Salvage harvesting is cutting pines already killed by MPB from which the beetles have departed. This frequently occurs in conjunction with sanitation. Therefore, the tactics are combined under this alternative, although salvage harvesting does not affect the MPB population directly. The removal of currently infested and recently killed pines in a stand can serve as a starting point for a silvicultural treatment (see Alternative 2), as it will reduce the basal area and tree diameter in the infested patches.

Alternative 4: Infested Tree Treatment - Cut and individually treat infested pines prior to the maturation and emergence of MPB, which can begin as early as mid-July. Any action that kills most or all of the MPB within infested trees prior to MPB emergence, falls under this direct control action alternative. The following examples do not work in all situations and are not all supported by rigorous research results. Examples of infested tree treatment techniques are as follows: (1) Cut and burn on site; (2) Cut and bury at least 6 inches deep on site; (3) Cut and chip; (4) Cut and remove the bark from infested portions of logs before the immature MPB transform to adult beetles; (5) Cut and expose to direct sunlight such that the trunk surface receives sufficient heat to kill the beetles under the bark; (6) Cut and cover with thick clear plastic such that the trunk surface receives sufficient heat to kill the beetles under the bark; (7) Cut and treat infested logs with an approved, registered insecticide in accordance with label directions (currently, only a few formulations of lindane, usually labelled as some brand of 'borer spray,' remain available to

[illegible] conserved groups and individuals, including [illegible] Forest Service personnel. [illegible] [illegible] alternative:

[illegible] 1: [illegible] Accept [illegible] undocumented impacts caused by MPB [illegible] MPB [illegible] associated with pine forests [illegible] [illegible] of pine forests [illegible] MPB population [illegible] [illegible] [illegible] MPB [illegible] [illegible] years [illegible]. These [illegible] depending upon the expected [illegible]

[illegible] 2: Silvicultural Treatment. [illegible] [illegible] of MPB [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] square feet of basal area [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] by MPB is [illegible] "salvage harvest" [illegible] under Alternative 3.

Alternative 3: [illegible] Salvage Harvesting: [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] MPB [illegible] [illegible] MPB [illegible] [illegible] salvage harvesting [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] under this alternative, although salvage [illegible] [illegible] MPB.

[illegible] The removal of currently infested and recently killed [illegible] [illegible] silvicultural treatment [illegible] Alternative 2, [illegible] [illegible] and [illegible] infested patches.

[illegible] [illegible] treatment [illegible] individually [illegible] [illegible] [illegible] MPB, which [illegible] as early as mid-July. Any [illegible] [illegible] [illegible] MPB emergence [illegible] direct [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] treatment [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] MPB [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

treat infested logs). It is important to check any treatment near the end of June. If excessive MPB survival is noted, option (7), chemical treatment, could still be performed to prevent MPB emergence. Infested tree treatment differs from sanitation harvesting (Alternative 3), only because it is usually applied on a smaller scale and is often not conducted in conjunction with salvage harvesting.

Alternative 5: Protection of High Value Trees - Prior to the attack period of MPB, which can begin as early as mid-July, the stems of living, green, uninfested trees which are of high value are sprayed with an approved, labeled insecticide that repels and/or kills attacking MPB and prevents infestation. Currently, certain specific formulations of carbaryl and permethrin are available for this use in Colorado and have shown some efficacy against MPB when properly applied.

Appendix 2: Predictions and Recommendations for the Jamestown Area

The action alternatives described in Appendix 1 were used to discuss probable outcomes of implementing a specific alternative and to frame predictions for the Jamestown area: This information, provided in the fall and winter of 1998 - 1999 to the various concerned groups and individuals, including USDA Forest Service personnel, is summarized below.

It is important to realize that these action alternatives apply to specific, individual stands. The effect of treatments against MPB on a landscape or multiple-stand basis, have received little research attention and are not well documented or understood. MPB dispersal is thought to be primarily localized within a few hundred yards for most of a population, but long distance dispersal is possible and also not well understood.

Alternative 1: Do Nothing. Should the MPB population continue to thrive and increase, outstripping the dampening effects of weather and natural enemies, I expect that between 50 to 200 pines in and near the stand burned by the Jamestown prescribed fire will be attacked, colonized, and killed in the late summer of 1999. My limited knowledge of the general area indicates that the burned stand is one of the most suitable places for MPB, so that most of this pine mortality would occur in trees adjacent to the "1998 Kills" (Table 1). A significant hazard of infestation exists for the many susceptible pines, often in dense clumps, located near houses that are in close proximity to the eastern border of the burn. Even in a rising MPB epidemic, individual spots of mortality may not expand in succeeding years. Examination of the heavily infested pines in the late spring will provide some insight as to the MPB population trajectory. It is expected that the general situation in the Jamestown area and along the Front Range will continue to favor MPB for several years.

Alternative 2: Silvicultural Treatment. Mortality from the combined effects of MPB and the prescribed fire will reduce the average stand density and diameter of living pines, but not in a consistent pattern that would eliminate pockets of highly susceptible pines. This combined mortality by itself does not constitute an effective silvicultural treatment against MPB. Silvicultural treatment of the stand as described above would result in conditions far less favorable or attractive to MPB. It is the only long-term action that would address the cause of MPB mortality, a susceptible stand condition, rather than the other strategies which address the symptom of these stand conditions; too many beetles in one place at one time. Implementation would need to occur in the late fall and winter, so that the residual stand would have the maximum amount of time to recover and so that no attraction would result from having freshly cut pine in the stand. There is some risk that thinning shock would lower tree resistance of the residual pines to MPB attack for one to two years. Silvicultural treatment might conflict with the stated objectives of the prescribed fire parameters, which were reducing fuels while causing no more than 20% mortality in the

stand. A conflict exists because people and MPB both prefer larger, older ponderosa pine stands. Densities and tree spacings which discourage the beetles may appear too open for the public.

Alternative 3: Sanitation/Salvage Harvesting. This alternative does not really apply to the stand burned by the prescribed fire, because there is so little MPB mortality that salvage is not an issue. In addition, snag recruitment is desired in the area. Sanitation will be discussed in the next section under Alternative 4.

Alternative 4: Infested Tree Treatment. The relatively small number and localized nature of the "1998 KILLS" (Table 1) renders this alternative viable. It would remove the known sources of MPB contagion from within the burned stand by treating successfully colonized pines. While some MPB immigration might occur from surrounding areas, this alternative would be expected to drastically reduce the number of pines predicted to be killed by MPB in this stand in 1999. Unsuccessfully attacked pines are more likely to become the initially colonized, focus trees of group infestations in future years, as compared with apparently healthy pines not attacked by MPB. It must be stressed that unsuccessfully attacked pines will not produce significant numbers of MPB adults in 1999, and are not a source of MPB contagion, since they were not successfully colonized. However, because unsuccessfully attacked pines have a heightened attractiveness and because it is difficult to find and properly identify every successfully attacked, colonized tree, the most effective implementation of this alternative would be to treat most, or all of the "1998 PITCHOUTS" (Table 1), as if they, too, had been colonized. This would make individual tree treatment much less efficient, as it is very labor intensive and the number of trees needing some treatment would be increased. Sanitation logging might be the best tool to accomplish such a full-scale treatment (see Alternative 3: Sanitation/Salvage Harvesting in the Action Alternatives section above). One action, logging, would mitigate the hazard presented by both colonized, "contagious" trees, and attacked "non-contagious" trees. Given my understanding of the land management objectives for the area, I recommend some form of this alternative as the most appropriate way to deal with the MPB situation in the Jamestown prescribed fire area.

Alternative 5: Protection of High Value Trees. This alternative is not appropriate for a 43-acre area in which there are thousands of susceptible trees, and among which one cannot readily distinguish those of especially high value. The major application expense and indirect impacts of such a large quantity of pesticide are "costs" that are not justified by the "benefits" of preventing tree mortality. It would be a very prudent precaution on the adjacent private property, particularly if the "no action" alternative is selected for the burned stand. Annual treatment is necessary for the duration of elevated MPB activity in the vicinity if this preventive treatment strategy is to be successful.

Appendix 3: Public Involvement

At the request of the Boulder Ranger District, I attended various meetings and field trips in order to provide information on forest insects, tree diseases and other related topics, and to discuss the information developed for this report. These contacts are listed in Table 4. Additional contacts were made on the telephone and in person regarding the MPB situation in the Jamestown area and along the Front Range in Boulder County.

Table 4. List of meetings attended by USDA Forest Service Entomologist, W. C. Schaupp, Jr., which concerned the Jamestown, Colorado, prescribed fire of May 4, 1998, and the activity of the mountain pine beetle in the vicinity of the fire

DATE	REPRESENTED GROUPS	CONCERNING
9/8/1998	Arapaho and Roosevelt National Forest, USFS Boulder Ranger District, Colorado State Forest Service-Boulder District, Boulder County Parks and Open Space, others	Field trip to Jamestown prescribed fire site
10/28/1998	Arapaho and Roosevelt National Forest-Supervisor's Office, USFS Boulder Ranger District, Colorado State Forest Service-Boulder District, Boulder County Parks and Open Space, City of Boulder-Mountain Parks, City of Boulder-Open Space	Report findings to Boulder County Ecosystem Cooperative, discuss possible responses and develop talking points for public information regarding forest health and the mountain pine beetle situation
01/08/1999	Arapaho and Roosevelt National Forest-Supervisor's Office, USFS Boulder Ranger District, Colorado State Forest Service-Boulder District, Colorado State Forest Service-State Office	Discuss various agency positions and options for action in light of MPB situation in Jamestown prescribed fire
01/15/1999	Jamestown Mountain Pine Beetle Task Force	Report findings to Task Force, discuss options for action and recommendations at Jamestown private residence
02/01/1999	Jamestown Board, private citizens and residents of Jamestown, USFS Boulder Ranger District, Colorado State Forest Service-Boulder District	Provide information upon request at the monthly town meeting held by the Jamestown Board, when they received Jamestown Mountain Pine Beetle Task Force recommendations, discussed the issues with attendees, and voted to adopt the Task Force recommendations
03/19/1999	Private citizens, including members of the Jamestown Mountain Pine Beetle Task Force	Display and discuss the action alternative that is to be implemented by walking through the stand affected by the prescribed fire and inspecting the tree marking and survey results